# Triglyceride-glucose index on risk of adverse events after drug-coated balloon angioplasty

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## Abstract

**Background**  The pathogenetic mechanism of atherosclerotic cardiovascular diseases is associated with insulin resistance (IR), which serves as a metabolic risk factor. As a novel indication for IR, triglyceride-glucose (TyG) index may predict cardiovascular disease outcomes.

**Methods**  In current study, a cohort of 157 individuals with newly developed de novo lesions who received DCB angioplasty between January 2017 and May 2021 were included. The midterm follow-up clinical results consisted of the presence of vessel-oriented composite endpoint (VOCE). The baseline TyG index was divided into three groups by tertiles. This study compared various clinical characteristics and parameters among different groups during DCB angioplasty. A multivariate Cox regression model was built to investigate the potential predictors.

**Results**  Higher TyG index indicated an increased risk of VOCE according to the adjusted model (HR = 4.0, 95%CI: 1.0-15.4, $P = 0.047$). A non-linear correlation was uncovered between the index and VOCE from the smooth curve. Based on Kaplan-Meier curve, individuals in the highest TyG index group were more likely to develop VOCE ($P < 0.05$ for log-rank).

**Conclusions**  The incidence of VOCE was shown to be independently and positively correlated with an elevated TyG index in individuals with de novo coronary lesions who received DCB angioplasty.

**Keywords**  Triglyceride-glucose index, Drug-coated balloons, De novo coronary artery lesions, Vessel-oriented composite endpoint

## Background

Drug-coated balloon (DCB) is commonly used in treating various cardiovascular diseases, and cardiologists commonly use the implant-free approach of DCB is widely used by cardiologists which is progressively becoming a standard therapeutic option. By enabling consistent administration of drugs that inhibit cell growth in the inner layer of blood vessels, DCB helps reduce vascular wall thickening and can potentially prevent vascular remodeling by locally dispersing cell-growth-inhibiting drugs [1]. DCBs are effective in treating de novo coronary artery disease, and other conditions [2–5]. The consensus [6] has guided the implementation of the optimal medical intervention. However, individuals who have received drug-coated angioplasty for a similar ailment may develop adverse clinical consequences [7], including vessel-oriented composite endpoint (VOCE). The risk factors and mechanisms of VOCE are complex. Recent studies have indicated that anatomical indexes such as post-procedural percent diameter stenosis (%DS) and post-procedural minimal lumen diameter (MLD) were

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associated with major adverse cardiovascular events [8, 9]. Identifying risk factors for vessel-focused composite endpoints is essential in developing efficient approaches to decrease the occurrence of VOCE, thus holding significant therapeutic significance.

Insulin resistance (IR) refers to the reduced ability of cells in the body to respond to insulin, which is commonly observed in patients with type 2 diabetes mellitus. This results in the impairment of insulin's ability to regulate glucose metabolism, leading to elevated blood glucose levels and a range of related health complications [10]. Homeostatic Model Assessment (HOMA) for IR and hyperinsulinemia-euglycemic clamp are more complex way to evaluate IR. Additionally, IR currently is the clinically recognized risk cardiometabolic factors for coronary heart disease and can lead to unsatisfactory clinical outcomes [11–13]. As the novel IR indicator, the triglyceride-glucose (TyG) index can affect the clinical

outcomes of individuals with coronary heart disease and other related conditions [14].

By exploring the connections between metabolic markers, coronary pathophysiology, and interventional methods, the study improved the understanding of the TyG index in predicting VOCE. The novel aspect of the IR-associated indicator is from the cardiovascular interventional operation application. This study aims to explore whether novel indicator can identify VOCE in patients undergoing DCB angioplasty at an early phase.

## Methods

### Study design and population

This study included patients with de novo coronary artery lesions who had undergone DCB angioplasty at Fujian Medical University Union Hospital between January 1, 2017, and May 31, 2021. A grand total of 157 individuals were categorized into three groups by tertiles (Fig. 1). The Ethics Committee of Fujian Medical University Union
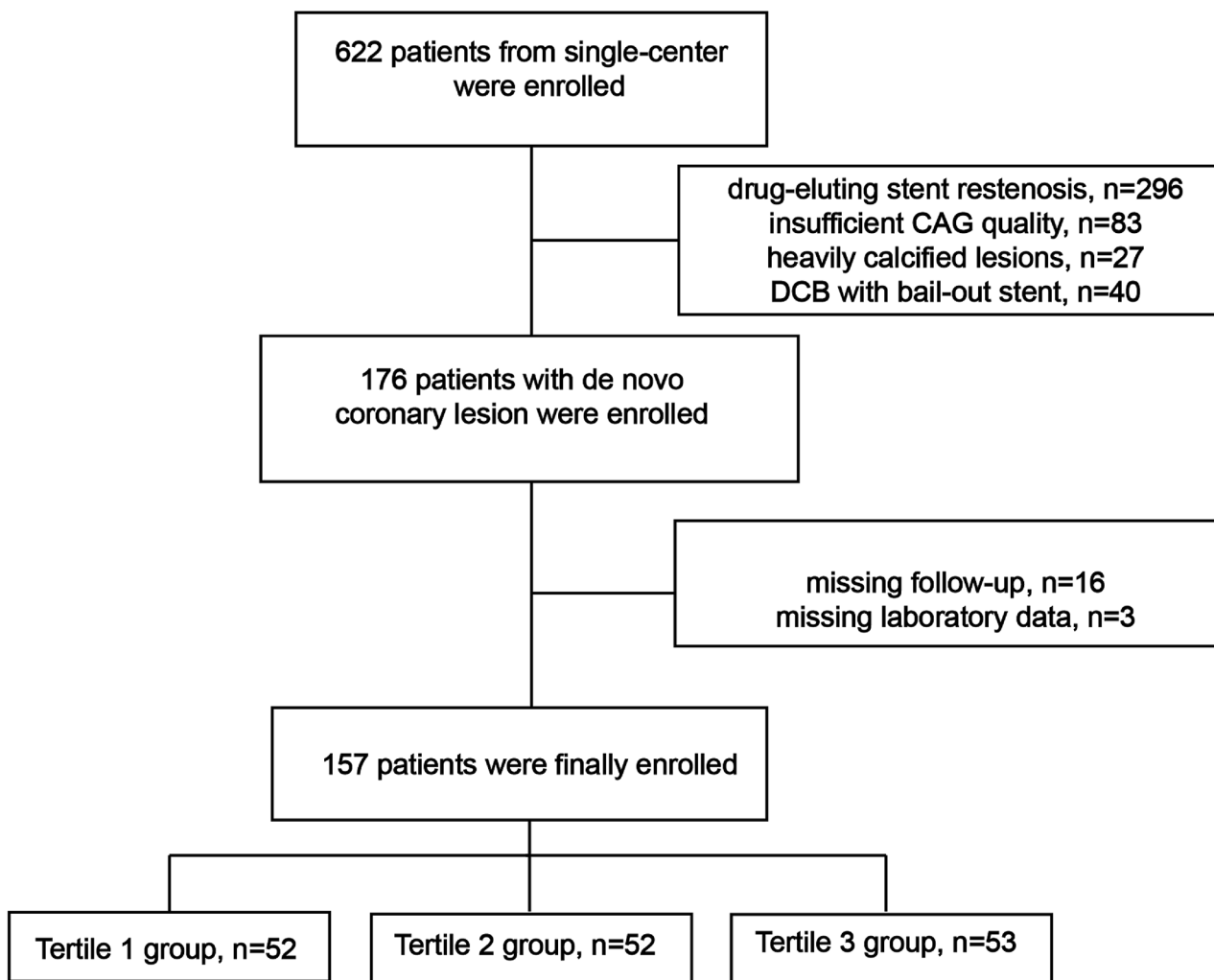


**Fig. 1** Flow chart of recruitment procedure

Hospital approved the study protocol and issued the procedure with the approval number 2023KY092. The current study conforms to the Helsinki Declaration.

### Inclusion criteria
Patients with available laboratory data, high-quality angiographic images, and de novo coronary artery lesions underwent DCB angioplasty were included.

### Exclusion criteria
The present study excluded those with incomplete data on laboratory data such as fasting glucose and fasting triglyceride etc. Additionally, individuals with left main coronary artery disease, ostial lesion, highly calcified or thrombotic lesion, and inadequate angiographic image quality were also excluded.

### Blood parameter measurements
Baseline blood samples were collected before the DCB angioplasty to test clinical laboratory indexes. Biochemical detector (Cobas 8000, Roche, Germany) was used to analyze fasting blood samples for plasma lipids, serum creatinine (SCr), and fasting blood glucose (FBG). Glycosylated hemoglobin analyzer (Sysmex G7, Japan) was used to detect hemoglobin A1c (HbA1c), which serves as an indicator of glycemic control level. Furthermore, the formula for calculating TyG index is as follows: $\ln[\text{Triglyceride (TG, mg/dL)} \times \text{FBG (mg/dL)} / 2]$.

### Statistics
Continuous variables that exhibited an approximately normal distribution were denoted as mean±standard deviation, when applicable. On the other hand, percentages were used to present for categorical variables. The study used one-way analysis of variance to examine differences in continuous variables across the TyG index tertiles. Sex, hypertension, current smoker, medication and additional categorical variables in this study were examined by Chi-square tests or Fisher's exact tests. The study also employed linear regression analyses to explore the potential relationship among the TyG index and other cardiovascular risk or protection factors, and a correlation heatmap was used to visualize these associations. Continuous variables comparison between the two different groups divided by clinical outcomes entailed the utilization of Student's t-test. To delve into the relationship between potential risk factors and VOCE prevalence, Cox regression analyses were conducted. Kaplan-Meier curves were used for achieving the survival information of different groups, and the statistical differences among varying levels of the TyG index groups were examined by the log-rank test. Additionally, a smooth curve in present study was employed to strengthen understanding of non-linear relationship between the TyG index and VOCE incidence.

A statistically significant result was determined if the $P < 0.05$. Statistical analyses were conducted using SPSS version 23.0 (SPSS Inc., Chicago, IL, USA), MedCalc version 11.4 (MedCalc Inc., Ostend, Belgium), and R statistical environment version 4.2.2.

## Results
296 patients with in-stent restenosis lesions received DCB angioplasty were excluded. Additionally, 83 patients with inadequate and low-quality Coronary angiography (CAG) images, 27 patients with highly calcified lesions, and 40 patients who underwent DCB with bail-out stenting were considered for exclusion. Of the 176 registered participants, 16 were excluded because they missed follow-up information, and three were excluded because they did not have FBG data. For this investigation, a cohort of 157 patients who underwent DCB angioplasty was included, and their follow-up over the midterm was documented.

Table 1 displays detailed baseline information on the patients. The average of the TyG index in different groups were 8.2±0.2, 8.7±0.1, and 9.4±0.4, correspondingly. The average age of the three distinct tiers of the TyG index groups were 64.1±10.3, 58.8±12.3, and 62.0±10.6, correspondingly.The TyG index's lowest tertiles exhibited the greatest level of high-density lipoprotein cholesterol (HDL-C) (1.1±0.3 compared to 1.0±0.3 and 1.0±0.3, $P < 0.001$). Tertile 3 had the highest TG levels, FBG levels, HbA1c levels, incidence of diabetes mellitus, and beta-blocker usage ($P < 0.05$). Three groups demonstrated no notable variations in age, body mass index (BMI), clinical presentation, laboratory findings, medication, lesion characteristics, gender, and DCB angioplasty parameters.

Table 2 demonstrates that the TyG index levels positively correlated with BMI, HbA1c, and low-density lipoprotein cholesterol (LDL-C) while displaying negative correlation with HDL-C ($P < 0.05$). The correlation heatmap in Fig. 2 displayed the connection among the cardiovascular laboratory variables. Throughout the midterm follow-up, the VOCE occurrences were documented, comprising of one (0.6%) cardiac death related to vessels, four (2.5%) myocardial infarctions related to vessels, and 13 (8.3%) revascularizations driven by ischemia in the target vessel. The analysis for VOCE using Cox regression is displayed in Table 3. Elevated TyG index values are associated with a higher risk of VOCE (Tertile 3 group HR 4.0, 95% CI 1.0, 15.4, $P = 0.047$). A noteworthy point is that the predictive capability remained even after adjusting for LVEF, age, Scr, HbA1C, LDL, hypertension, acute coronary syndrome, HDL, BMI, sex, current smoke status, and DM ($P = 0.022$ for the trend).

**Table 1** Baseline laboratory indicators, medication, vessel and DCB characteristics by tertiles of the TyG index

| Variable | Tertile 1 (n = 52) | Tertile 2 (n = 52) | Tertile 3 (n = 53) | P value |
|---|---|---|---|---|
| TyG index | 8.2 ± 0.2 | 8.7 ± 0.1 | 9.4 ± 0.4 | < 0.001 |
| Age,years | 64.1 ± 10.3 | 58.8 ± 12.3 | 62.0 ± 10.6 | 0.056 |
| Body mass index,kg/m2 | 23.8 ± 2.9 | 24.9 ± 3.2 | 25.0 ± 3.0 | 0.059 |
| LDL-C,mmol/L | 2.7 ± 1.0 | 2.7 ± 1.0 | 2.9 ± 1.3 | 0.547 |
| TC,mmol/L | 4.0 ± 1.1 | 4.1 ± 1.1 | 4.4 ± 1.4 | 0.143 |
| HDL-C,mmol/L | 1.1 ± 0.3 | 1.0 ± 0.3 | 1.0 ± 0.3 | < 0.001 |
| SCr,umol/L | 75.6 ± 21.8 | 91.4 ± 85.7 | 79.1 ± 20.6 | 0.272 |
| LVEF,% | 63.0 ± 9.8 | 63.8 ± 8.9 | 63.3 ± 10.3 | 0.916 |
| triglyceride,mg/dL | 83.3 ± 18.7 | 131.1 ± 23.7 | 206.5 ± 91.0 | < 0.001 |
| Fasting blood glucose,mg/dL | 94.4 ± 17.0 | 99.0 ± 15.5 | 134.6 ± 45.8 | < 0.001 |
| Hemoglobin A1C,% | 6.5 ± 1.1 | 6.6 ± 1.5 | 7.3 ± 1.6 | 0.007 |
| Reference vessel diameter,mm | 2.5 ± 0.7 | 2.6 ± 0.8 | 2.5 ± 0.6 | 0.521 |
| Maximum drug-coated balloon diameter,mm | 2.6 ± 0.4 | 2.7 ± 0.4 | 2.6 ± 0.5 | 0.798 |
| Maximum drug-coated pressure, atm | 10.8 ± 2.0 | 10.3 ± 2.4 | 10.8 ± 3.0 | 0.532 |
| Men,n(%) | 39 (75.0%) | 41 (78.8%) | 42 (79.2%) | 0.847 |
| ACS,n(%) | 43 (82.7%) | 44 (84.6%) | 45 (84.9%) | 0.945 |
| Hypertension,n(%) | 33 (63.5%) | 34 (65.4%) | 36 (67.9%) | 0.89 |
| Diabetes mellitus,n(%) | 16 (30.8%) | 17 (32.7%) | 33 (62.3%) | 0.001 |
| Current smoker,n(%) | 19 (36.5%) | 14 (26.9%) | 14 (26.4%) | 0.445 |
| ACEI/ARB/ARNI,n(%) | 29 (55.8%) | 31 (59.6%) | 30 (56.6%) | 0.917 |
| Beta-blocker,n(%) | 34 (65.4%) | 30 (57.7%) | 47 (88.7%) | 0.001 |
| Statins,n(%) | 52 (100.0%) | 52 (100.0%) | 52 (98.1%) | 0.373 |
| Ticagrelor,n(%) | 36 (69.2%) | 36 (69.2%) | 44 (83.0%) | 0.177 |
| Clopidogrel,n(%) | 15 (28.8%) | 16 (30.8%) | 9 (17.0%) | 0.213 |
| Aspirin,n(%) | 50 (96.2%) | 50 (96.2%) | 50 (94.3%) | 0.873 |
| Type of predilation drug | | | | 0.419 |
| Cutting balloon,n(%) | 21 (40.4%) | 13 (25.0%) | 15 (28.3%) | |
| Semicompliant balloon,n(%) | 23 (44.2%) | 23 (44.2%) | 27 (50.9%) | |
| Noncompliant balloon,n(%) | 2 (3.8%) | 5 (9.6%) | 2 (3.8%) | |
| Both/All,n(%) | 6 (11.5%) | 11 (21.2%) | 9 (17.0%) | |
| Type of target vessel | | | | 0.198 |
| LAD,n(%) | 25 (48.1%) | 24 (46.2%) | 25 (47.2%) | |
| LCX,n(%) | 17 (32.7%) | 16 (30.8%) | 10 (18.9%) | |
| RCA,n(%) | 5 (9.6%) | 11 (21.2%) | 12 (22.6%) | |
| Branch,,n(%) | 5 (9.6%) | 1 (1.9%) | 6 (11.3%) | |
| Post-procedure TIMI grade 3 flow,n(%) | 51 (98.1%) | 51 (98.1%) | 52 (98.1%) | 1.000 |
| Drug coated balloon diameter to vessel diameter ratio(1:1),n(%) | 12 (23.1%) | 12 (23.1%) | 12 (22.6%) | 0.998 |

The data is presented as either a number (%) or as the mean ± standard deviation (SD). ACEI refers to angiotensin-converting enzyme inhibitor, while ARB stands for angiotensin II receptor blocker. SCr represents serum creatinine, LVEF represents left ventricular ejection fraction, ACS represents acute coronary syndrome, LAD represents left anterior descending artery, LCX represents left circumflex artery, LDL-C represents low-density lipoprotein cholesterol, RCA represents right coronary artery, RLD represents reference lumen diameter, TC represents total cholesterol, TIMI stands for thrombolysis in myocardial infarction, and TyG index refers to triglyceride-glucose index

**Table 2** Analysis of TyG index and cardiovascular associated factors using both univariate and multivariate linear regression

| Variable | Univariate | | Multivariate | |
|---|---|---|---|---|
| | β(95% CI) | P value | β(95% CI) | P value |
| HbA1c | 0.1110 (0.0535, 0.1684) | < 0.001 | 0.1168 (0.0645, 0.1691) | < 0.001 |
| BMI | 0.0413 (0.0134, 0.0692) | 0.004 | 0.0398 (0.0147, 0.0649) | 0.002 |
| HDL-C | -0.5769 (-0.8829, -0.2708) | < 0.001 | -0.6715 (-0.9702, -0.3728) | < 0.001 |
| Scr | 0.0005 (-0.0012, 0.0021) | 0.583 | 0.0002 (-0.0014, 0.0017) | 0.845 |
| LDL-C | 0.0697 (-0.0078, 0.1471) | 0.080 | 0.1171 (0.0461, 0.1881) | 0.001 |

Abbreviations see Table 1

**Fig. 2** Correlation heatmap among cardiovascular laboratory factors

**Table 3** Baseline TyG index and prediction of VOCE

| TyG index groups | Non-adjusted model | | Full-adjusted model | |
|---|---|---|---|---|
| | HR (95% CI) | P value | HR (95% CI) | P value |
| T1 | Ref | | Ref | |
| T2 | 0.6 (0.1, 2.5) | 0.481 | 0.9 (0.2, 4.5) | 0.92 |
| T3 | 2.0 (0.7, 6.0) | 0.198 | 4.0 (1.0, 15.4) | 0.047 |
| P for-trend | | 0.124 | | 0.022 |

The variables that were modified in full-adujsted model included LVEF, age, serum creatinine, sex, HbA1c, low-density lipoprotein, hypertension, acute coronary syndrome, high-density lipoprotein, body mass index, current smoking status, diabetes mellitus

After analyzing their clinical outcomes using CAG images during follow-up, the present study categorized them into two groups: the VOCE group consisting of 18 patients and the non-VOCE group consisting of 139 patients. In the non-VOCE group, the median follow-up time was 345 days, while in the VOCE group it was 278 days ($P>0.05$). Table 4 displays the features of the lesions and procedures. Out of the 157 vessels assessed, 64 (46.0%) in the non-VOCE group and 10 (55.6%) in the VOCE group were identified as left anterior descending arteries. Additionally, 38 (27.3%) in the non-VOCE group and five (27.8%) in the VOCE group were associated with

left circumflex arteries. Moreover, 25 (18.0%) in the non-VOCE group and three (16.7%) in the VOCE group were linked to right coronary arteries. Lastly, 12 (8.6%) in the non-VOCE group were identified to be branches of coronary arteries. No notable variances were observed in the categories of predilation balloons and the proportion of DCB diameter to vessel diameter 1:1, post-procedural thrombolysis in myocardial infarction (TIMI) grade 3 flow, maximum DCB diameter, maximum DCB pressure, and reference vessel diameter (RVD). Table 4 displays that individuals in different groups were similar to age, gender, BMI, clinical symptoms, laboratory results, and medication, except for a higher prevalence of hypertension (69.1% vs. 38.9%, $P=0.011$) in the non-VOCE group compared to the VOCE group. Table 5 presents the factors that exhibited a notable connection with an elevated risk of VOCE. These factors include the TyG index (HR 2.3, 95%Cl 1.0–5.1, $P=0.047$). Upon accounting for covariates, the multivariable analysis demonstrated a continued and substantial correlation between the TyG index (HR 4.0, 95% CI 1.1–14.7, $P=0.035$) and an escalated risk of VOCE.

Based on the assessment of the Kaplan–Meier curve presented in Fig. 3, the cohort with a TyG index exceeding 8.95 exhibited inferior outcomes throughout the

**Table 4** Clinical and lesion characteristics

| Variables | Non-VOCE(n = 139) | VOCE(n = 18) | *P*-value |
|---|---|---|---|
| Age,years | 62 ± 11 | 59 ± 13 | 0.207 |
| Body mass index,kg/m² | 24.7 ± 3.1 | 23.6 ± 2.6 | 0.155 |
| LDL-C,mmol/L | 2.7 ± 1.1 | 3.0 ± 1.4 | 0.34 |
| TC,mmol/L | 4.1 ± 1.2 | 4.5 ± 1.4 | 0.225 |
| HDL-C,mmol/L | 1.0 ± 0.3 | 1.1 ± 0.3 | 0.514 |
| SCr,umol/L | 83.2 ± 55.5 | 73.2 ± 9.6 | 0.448 |
| LVEF,% | 63.4 ± 9.5 | 63.3 ± 11.2 | 0.965 |
| Triglyceride,mg/L | 138.3 ± 74.7 | 159.9 ± 79.0 | 0.253 |
| Triglyceride-glucose index | 8.8 ± 0.5 | 9.0 ± 0.6 | 0.058 |
| Fasting blood glucose,mg/dL | 107.7 ± 34.0 | 123.3 ± 37.6 | 0.072 |
| Hemoglobin A1C,% | 6.8 ± 1.5 | 7.0 ± 1.4 | 0.485 |
| Reference vessel diameter,mm | 2.6 ± 0.7 | 2.4 ± 0.6 | 0.371 |
| Maximum drug-coated balloon diameter,mm | 2.6 ± 0.5 | 2.7 ± 0.5 | 0.747 |
| Maximum drug-coated pressure, atm | 10.6 ± 2.6 | 10.6 ± 2.1 | 0.972 |
| Men,n(%) | 106 (76.3%) | 16 (88.9%) | 0.226 |
| ACS,n(%) | 117 (84.2%) | 15 (83.3%) | 0.927 |
| Hypertension,n(%) | 96 (69.1%) | 7 (38.9%) | 0.011 |
| Diabetes mellitus,n(%) | 57 (41.0%) | 9 (50.0%) | 0.467 |
| Current smoker,n(%) | 39 (28.1%) | 8 (44.4%) | 0.153 |
| ACEI/ARB/ARNI,n(%) | 81 (58.3%) | 9 (50.0%) | 0.504 |
| Beta-blocker,n(%) | 97 (69.8%) | 14 (77.8%) | 0.483 |
| Statins,n(%) | 138 (99.3%) | 18 (100.0%) | 0.718 |
| Ticagrelor,n(%) | 105 (75.5%) | 11 (61.1%) | 0.19 |
| Clopidogrel,n(%) | 33 (23.7%) | 7 (38.9%) | 0.165 |
| Aspirin,n(%) | 132 (95.0%) | 18 (100.0%) | 0.33 |
| Type of predilation drug | | | 0.538 |
| Cutting balloon,n(%) | 42 (30.2%) | 7 (38.9%) | |
| Semicompliant balloon,n(%) | 67 (48.2%) | 6 (33.3%) | |
| Noncompliant balloon,n(%) | 7 (5.0%) | 2 (11.1%) | |
| Both/All,n(%) | 23 (16.5%) | 3 (16.7%) | |
| Type of target vessel | | | 0.598 |
| LAD,n(%) | 64 (46.0%) | 10 (55.6%) | |
| LCX,n(%) | 38 (27.3%) | 5 (27.8%) | |
| RCA,n(%) | 25 (18.0%) | 3 (16.7%) | |
| Branch,,n(%) | 12 (8.6%) | 0 (0.0%) | |
| Post-procedure TIMI grade 3 flow,n(%) | 137 (98.6%) | 17 (94.4%) | 0.23 |
| Drug-coated balloon diameter to vessel diameter ratio(1:1),n(%) | 137 (98.6%) | 17 (94.4%) | 0.23 |

Abbreviations see Table 1

mid-term follow-up phase. Utilizing the outcomes of the tertile 2 group as a baseline, the log-rank test demonstrated a noteworthy disparity between the tertile 2 and tertile 3 groups (*P*=0.037). The application of a smooth curve fitting method to investigate the positive correlation between the TyG index and VOCE is illustrated by Fig. 4.

## Discussion

Based on the present understanding, this study is the first investigation that focused on the relationship between clinical outcomes and the novel index in patients with de novo coronary lesions who received DCB angioplasty. The primary outcomes of this investigation were

as follows: (1) The TyG indicator exhibited a correlation with cardiovascular laboratory variables. (2) Higher TyG index levels were associated with unfavorable cardiovascular clinical outcomes during the midterm follow-up period. (3) Increased TyG index levels, whether measured continuously or categorically, were found to be independently linked to a heightened risk of VOCE in the fully adjusted model, accounting for confounding factors.

Inflammation is a significant cause of a variety of heart conditions [15, 16]. The interaction of genetic, environmental, and behavioral influences induces IR. The reduced sensitivity and responsiveness of insulin affects the metabolism of fats and sugar, potentially worsening high blood glucose levels and abnormal lipid levels. An

**Table 5** Associated factors with VOCE

| Variables | Univariate analysis | | Multivariate analysis | |
|---|---|---|---|---|
| | HR(95%CI) | P-Value | HR(95%CI) | P-Value |
| Triglyceride-glucose index | 2.3 (1.0, 5.1) | 0.047 | 4.0 (1.1, 14.7) | 0.035 |
| Maximum drug-coated pressure, atm | 0.9 (0.8, 1.1) | 0.489 | | |
| Post-procedure TIMI grade 3 flow,n(%) | 0.3 (0.0, 2.5) | 0.274 | | |
| Maximum drug-coated balloon diameter,mm | 1.2 (0.5, 3.3) | 0.651 | | |
| ACS | 0.9 (0.3, 3.2) | 0.899 | | |
| Hemoglobin A1C | 1.1 (0.8, 1.4) | 0.586 | | |
| LVEF | 1.0 (1.0, 1.1) | 0.85 | | |
| SCr | 1.0 (1.0, 1.0) | 0.322 | | |
| HDL-C | 2.8 (0.5, 16.2) | 0.24 | | |
| Hypertension | 0.4 (0.1, 1.0) | 0.044 | | |
| LDL-C | 1.3 (0.9, 1.9) | 0.172 | | |
| TC | 1.3 (1.0, 1.9) | 0.089 | | |
| Diabetes mellitus | 1.3 (0.5, 3.2) | 0.156 | | |
| BMI | 0.9 (0.8, 1.0) | 0.156 | | |
| Current smoker | 2.0 (0.8, 5.2) | 0.133 | | |

Abbreviations see Table 1
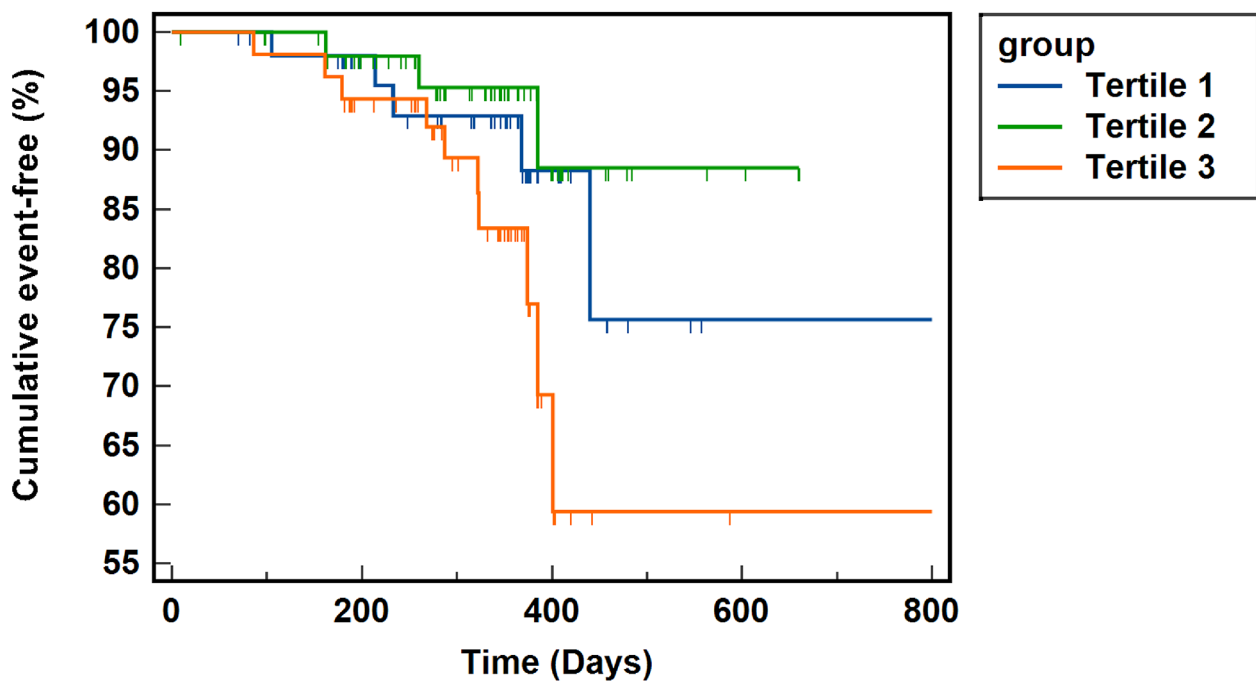


**Fig. 3** Patients who underwent drug-coated balloon angioplasty were analyzed using Kaplan-Meier curves

association has been found between high HbA1c levels and cardiovascular risk, according to a randomized clinical trial [17]. The association of TyG index and VOCE incidence being independent of HbA1C suggests that TyG index may provide additional information regarding cardiovascular risk factors, such as atherogenic lipoprotein, which is beyond traditional glucose control indicator. TG and parts of cholesterol are transported in the circulation by TG-rich lipoproteins (TRL) that contain chylomicrons and very low-density lipoprotein (VLDL).

The development of atherosclerotic injury is triggered and exacerbated by atherogenic lipoproteins, specifically LDL, VLDL, and TRL [18, 19]. The aforementioned lipoproteins promote the accumulation of lipids, formation of foam cells, inflammatory responses, and dysfunction of the endothelial cells. Researches indicates that patients with chronic diseases like prediabetes may face a higher cardiovascular risk due to elevated plasma levels of TRL [20, 21]. TRL plays a pivotal role in the progression of atherosclerosis and should be an indispensable focus
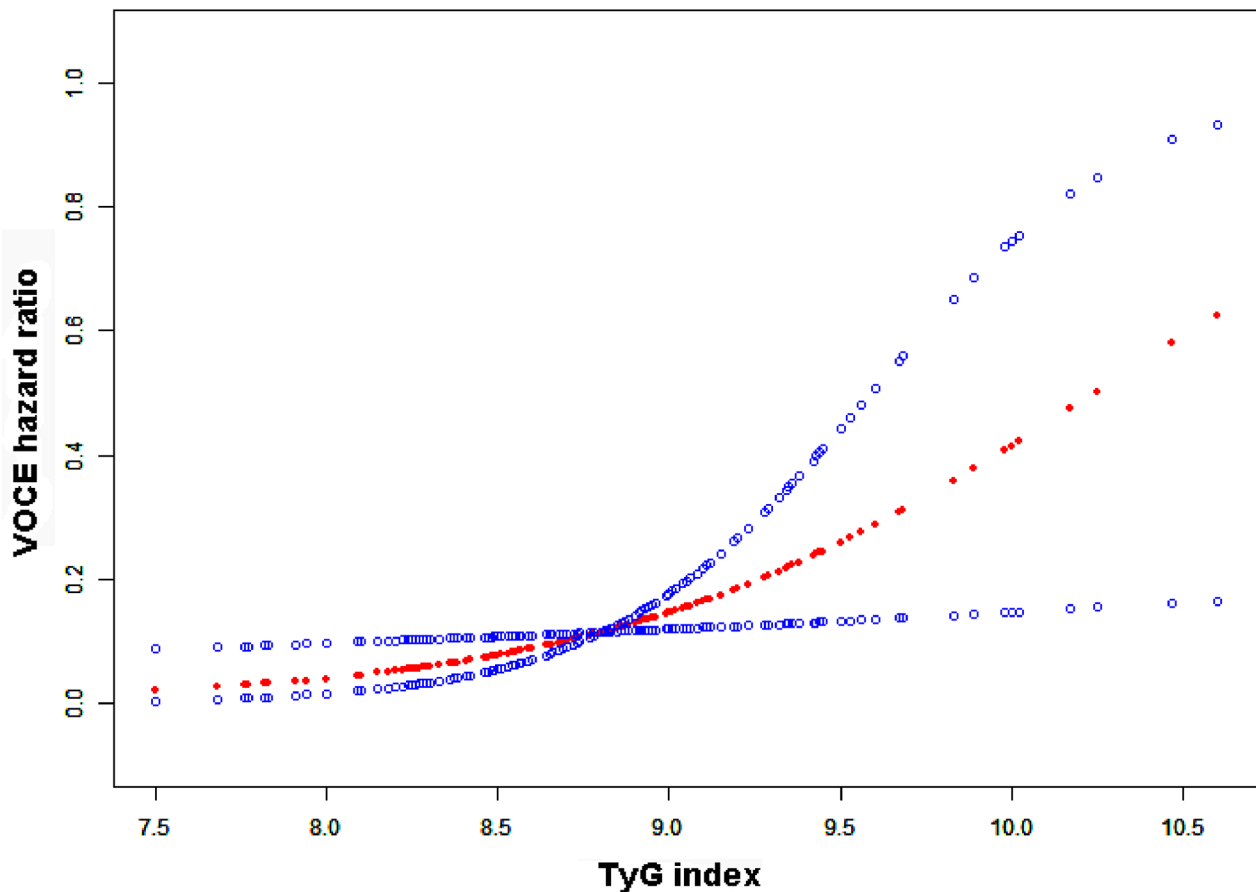
**Fig. 4** The correlation between the TyG index and VOCE. The smooth curve fitting between variables is represented by a solid line in the middle. The dashed line on either side indicates a 95% CI for the fit. The TyG index displays the population density through a black and white strip at the bottom. Model was adjusted for LVEF, age, Scr, sex, HbA1C, LDL, hypertension, ACS, HDL, BMI, current smoke status and DM

for both therapeutic intervention and research aimed at reducing cardiovascular risk in the future. Several previous metabolism associated studies demonstrated the index was a more reliable and superior IR biomarker [22, 23]. The worldwide incidence of cardiovascular diseases linked to IR is on the rise, primarily attributed to vascular stiffness, a recognized risk factor for coronary arteriosclerosis [24]. Previous research indicated that the TyG index could positively correlated with arterial rigidity, plaque formation in the carotid artery, damage to the microvessels in the kidneys, and diseases affecting the brain [25, 26]. Microvascular or macrovascular injury may be observed in patients after DCB angioplasty. The mechanism of vascular stiffness may be associated with IR which depresses the production of nitric oxide (NO). The progression of coronary artery disease in individuals with long-term survival periods may be closely associated with inflammation and vascular cell migration caused by NO [27]. Ion theory displays that the amiloride-sensitive channel known as the endothelial cell Na+ channel is crucial in vascular stiffness. Emerging evidence

demonstrates that activated endothelium Na+channel (EnNaC) contributed to cardiovascular stiffening, while activated endothelial cell mineralocorticoid receptor (ECMR) may induce endothelial cell stiffness by EnNaC [27–29]. Based on ion theory, the mechanism of vascular stiffness was dependent on increased ECMR and EnNaC.

It remains unclear how the TyG index affects cardiovascular clinical outcomes. Within the CUN cohort study, which centered around the vascular metabolism of 5014 healthy Caucasian individuals, a significant association was observed. A recent study demonstrated the novel IR index was positively associated with subsequent cardiovascular events [30]. As the TyG index becomes an increasingly important factor in assessing the risk, the index can aid in making informed clinical decisions and developing preventive strategies. Atherogenic lipoproteins are significantly reduced by proprotein convertase subtilisin/kexin type 9 inhibitors (PCSK9-i), leading to a lower incidence of myocardial infarction and stroke. Long-term mortality risk following acute coronary syndrome may be reduced with PCSK9-i when combined

with intensive statin therapy [31]. Moreover, PCSK9-i has effectively reduced atherogenic risk in patients with familial hypercholesterolemia [32]. This study highlights the significant role of PCSK9-i in lipid-lowering therapy for high-risk cardiovascular patients, which can enhance and optimize individual lipid management treatments. It is crucial to use PCSK9-i as a component of a more comprehensive cardiovascular risk management strategy. Prospective studies can be conducted to investigate if combining PCSK9-i treatment with DCB angioplasty can decrease the occurrence of VOCE. The TyG index in Koreans without diabetes mellitus exhibited greater predictive ability for ischemic heart disease than FBG or TG [33] [1]. The TyG index demonstrated a noteworthy influence on the progression of cardiovascular disease, cardiovascular mortality, and myocardial infarction, particularly within low-income countries. This was discovered in the Prospective Urban Rural Epidemiology study, which included 141,243 participants from five continents [34]. Further research has indicated an elevated TyG index may provide an innovative indicator of coronary artery disease symptomatology [35, 36]. The TyG index in a longitudinal study conducted in Korea has the potential to independently predict coronary artery calcification [37]. Additionally, when the TyG index is included in the risk model for major adverse cardiac events in diabetic individuals with ACS, its predictive power is enhanced [38]. Anatomical measurements such as MLD and %DS are commonly employed in intervention to evaluate the extent of narrowing in the blood vessel using CAG. VOCE was identified to be correlated with the degree of vessel diameter stenosis observed on the angiography [39]. Hidekuni Kirigaya et al. discovered that the utilization of post-procedural %DS could potentially aid in making clinical judgments and enhance the overall clinical results for individuals undergoing balloon angioplasty [8]. During DCB angioplasty, individuals with de novo coronary lesions may benefit from the TyG index as a new prognostic factor. Additional research is required to validate if incorporating the TyG index with post-procedural %DS or other anatomical variables into an existing risk prediction model could enhance the capacity to identify patients susceptible to VOCE. Patients diagnosed with coronary artery disease who were admitted for coronary angiography and subsequently received DCB angioplasty have significantly increased as a result of advancements in non-implant intervention technology. Identifying and anticipating the risk of VOCE in conjunction with established risk factors is crucial. Before DCB angioplasty, cardiologists can potentially spot individuals at an elevated risk of developing certain conditions by monitoring fluctuations in their TyG index, and implementing preventative measures to delay or prevent their onset. Further research is needed to fully understand its potential in predicting long-term outcomes and identifying patients at risk of metabolic complications.

## Study strengths and limitations

This study efficiently investigates how the TyG index affects the clinical outcomes of patients who underwent DCB. This computational model for calculating the TyG index considers the levels of glucose and lipids in cardiovascular health. TG and glucose levels are frequent laboratory indicators that can be measured from blood samples obtained before the operation. The current study could potentially offer valuable insights into the cardiovascular intervention operation treatment through optimazed clinical management of the TyG index. All analyses were adjusted for important confounders. Regression analyses were conducted based on tertiles and continuous values of the TyG index.

The study has certain limitations. First, the retrospective single-center research has a small sample of individuals from the Chinese population. Consequently, the outcomes of the present investigation may not apply to other populations. Second, the TyG index was exclusively obtained from the study sample, necessitating further investigation to validate the threshold value. Third, this study only used the initial TyG index to explore its predictive value. Moreover, there was a lack of substantial proof regarding the combined impact of %DS, MLD, quantitative flow ratio, and the TyG index. Therefore, testing whether the coexistence of vessel anatomical or physiological parameters and the TyG index would increase cardiovascular risk is worthwhile. Fourth, this study solely focused on de novo coronary lesions, and the limited sample size prevented any investigation into other intricate forms of coronary lesions. Fifth, this study was not a preplanned analysis. The potential biases and confounding factors that were not adjusted for and could have influenced this observational analysis. Hence, future validation of the findings necessitates extensive, meticulously planned, and wide-ranging prospective multi-center investigations.

## Conclusions

Patients with a higher TyG index who received DCB angioplasty had a higher risk of VOCE. The index could be widely used in disease management to assist individuals in reducing the risk of developing VOCE after interventional operation, providing a convenient and cost-effective approach.

### List of Abbreviations
| | |
|---|---|
| ACEI | Angiotensin-converting enzyme inhibitor |
| ACS | Acute coronary syndrome |
| ARB | Angiotensin II receptor blocker |
| BMI | Body mass index |
| CAG | Coronary angiography |
| DCB | Drug-coated balloon |

| | |
|---|---|
| EnNaC | Endothelium Na + channel |
| ECMR | Endothelial cell mineralocorticoid receptor |
| FBG | Fasting blood glucose |
| HbA1c | Hemoglobin A1c |
| HDL-C | High-density lipoprotein cholesterol |
| IR | Insulin resistance |
| LAD | Left anterior descending artery |
| LCX | Left circumflex artery |
| LDL-C | Low-density lipoprotein cholesterol |
| LVEF | Left ventricular ejection fraction |
| MLD | Minimal lumen diameter |
| NO | Nitric oxide |
| PCSK9-i | Proprotein convertase subtilisin/kexin type 9 inhibitors |
| %DS | Percent diameter stenosis |
| RCA | Right coronary artery |
| RLD | Reference lumen diameter |
| SCr | Serum creatinine |
| TC | Total cholesterol |
| TG | Triglyceride |
| TyG | Triglyceride-glucose |
| TIMI | Thrombolysis in myocardial infarction |
| TRL | Triglyceride-rich lipoproteins |
| VOCE | Vessel-oriented composite endpoint |

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12944-023-01951-8.

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Supplementary Material 1

Supplementary Material 2

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## Authors' contributions
LZR and CLL contributed to design the conception of the study. LZR, HX, and LMS contributed to acquiring data for the work. LZR analysed the data and drafted the manuscript. LZR and CLL put forward strict and valuable suggestions for the revision of the original manuscript. All gave final approval and agreed to be accountable for all aspects of work, ensuring integrity and accuracy. All authors read and approved the final manuscript.

## Data Availability
The database used and/or analyzed for this study available from the corresponding author on reasonable request (Lianglong Chen; Email: lianglongchenxh@126.com).

## Declarations

### Ethics approval and consent to participate
The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Fujian Medical University Union Hospital (protocol code: 2023KY081). Informed consent was obtained from all participants involved in the study.

### Consent for publication
Not applicable.

### Competing interests
The authors declare no competing interests.

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